



RÉPUBLIQUE
FRANÇAISE

*Liberté
Égalité
Fraternité*



CNESMAG

#101 AUTUMN 2026



To the ISS
and beyond?

05 Horizons

06 Visions



10 Space take



12 Cosmoculture

One day all lunarians?

14 Leading light

"Europe must reinvent itself and find its place in international cooperation"

Frank De Winne, Head of LEO Exploration Group and Europe exploration programme implementation at ESA's Human and Robotic Exploration directorate



17 Pointers



18 Planet CNES

Human spaceflight and exploration: decision time for Europe



19/ European space at the crossroads

21/ Human spaceflight after the ISS

23/ Artemis takes a European turn

25/ Lunar pathways

26

Back to the future

From Hermes to Orion: a European human spaceflight odyssey



27

Talking ethics

The crow, the fox and the grapes



28

Constellation

Gallery of profiles



32

Stepping stones

Space experiments, from drawing board to data

34

Earth attractions



36

Open space

The world human spaceflight club

Read the magazine on line



Ursula Aniakou-Serrant



Ursula first discovered a passion for space during her engineering school internship at the Guiana Space Centre. After occupying various functions in the field of space transportation, the deputy head of our foresight sub-directorate is today working on ecosystem support or launcher stage reuse. Her advice to youngsters is to dream big and never lose heart, even if your dreams may seem out of reach. For CNESMAG, she turns the spotlight on the high-thrust engine set to propel Europe into the realm of crewed spaceflight.

Sébastien Barde



Being involved in the great space exploration adventure is what motivates the head of our exploration and human spaceflight sub-directorate, who has occupied numerous posts at CNES over the last 30 years. As a member of the French delegation to ESA, he's now added a European string to his bow. Working alongside scientists and astronauts, in a domain that has a broad appeal, is what he's most proud of. He serves as our guide through this issue of CNESMAG, taking us from the magic of the CADMOS control room to the heart of international negotiations.

Pierre Emmery



While Pierre may be CNES's delegate to ESA for space exploration affairs, he still has his feet firmly on the ground. Our specialist in defending France's strategic interests explains for CNESMAG the intricacies of international affairs and the power stakes behind human spaceflight (technology demonstrations, innovation capabilities, etc.). Space is an international field in essence, and therefore a stimulating and multicultural playground that encourages youngsters to experiment. Working in this domain also gives a good perspective of what it takes to turn dreams into reality.

Pierre Le Metayer



Our exploration expert has always had close ties with space. After joining CNES in 2007 to work in the agency's scientific ballooning department, he subsequently occupied a series of cross-domain posts. Today, he's making France's voice heard in Europe and striving to forge international partnerships. Teamwork is what drives him, both inside and outside CNES: with the scientific sphere, industry, ministries and also young people. For him, it's important to convey the stuff of dreams that fuels crewed space exploration.



Boost the magazine on social media

Seen an article you like?
Don't hesitate to share it with your community.



@cnes



facebook.com/
CNESFrance



CNES



cnes_france



CnesFrance



CnesFrance



cnes.fr

CNESMAG, the magazine of the Centre National d'Etudes Spatiales, 2 place Maurice Quentin, 75039 Paris cedex 01. For all correspondence, write to 18, avenue Édouard Belin, 31401 Toulouse cedex 9. Tel.: 05 61 27 31 31. Website: <http://cnes.fr>. Subscriptions: <https://cnes.fr/cnesmag/abonnement>. **Publication director:** François Jacq. **Editorial director:** Séverine Klein. **Editor-in-chief:** Mélanie Ramel. **Proofreading:** Céline Arnaud. **Copywriters:** Dominique Fidel, Aude Borel, Hortense Lasbleis, Mélanie Ramel.

Photos and iconography: Loïc Octavia, Orianne Arnould, Ambre Bonnefoi (Photon).

Photo credits: Cover: © ESA/NASA/2026 ; p.4: CNES/Frédéric Maligne, CNES/Hervé Piraud ; p.5: CNES/Frédéric Maligne, p.6: CNES/Adrien Ribet, p.7: ESA/NASA/SpaceX, p.8: ESA, p.9: ESA/IPEV/PNRA-J.Studer, p.10 (top and bottom): ESA/NASA, p.11: ESA/NASA/Chris Williams, p.12 (left): Christophel Collection, p.12 (right): Public Domain, p.13 (top): Keoken Interactive, p.12-13 (bottom): Christophel Collection/20th Century Fox Film Corporation, p.13: CNES/Thierry de Prada, p.14 and 16: Felix Schmitt, p.17 (top): NASA/Bill Ingalls, p.17 (bottom): NASA/Keegan Barber, p.18-19: NASA/Jessica Meir, p.20: NASA/Jessica Meir, p.21: Vast Space, NASA, Starlab Space, p.21 (bottom): ESA/NASA, p.22 (top): CNES/Hervé Piraud, p.22 (bottom): CNES/Frédéric Maligne, p.23: NASA, p.24 (top): NASA/Ben Smegelsky, p.24 (bottom): CNES, p.25 (top): CNES/David Ducros, p.25 (bottom): CNES/ESA/Arianespace-ArianeGroup/CSG Photo & Video Dept./T Leduc, p.26: CNES/David Ducros, p.32: CNES/Emmanuel Grimaud, CNES/Alexandre Ollier, CNES, p.33: ESA/NASA, CNES/Emmanuel Grimaud, p.34: Musée de l'Armée/Anne-Sylvaine Marre-Noël, CNES, p.35: Novespace, CNES/ESA/Universcience/Hervé Piraud, (bottom) Stéphane Tidet

Illustrations: Citizen Press and Anne Cresci for Constellation.

Webmaster: Mathilde Tournier. **Social media:** Aurélie Marmu, Hermine Chaumolot, Marie Dupont (Citizen Press), Méliandre Lacaille (La Netscouade).

English text: Boyd Vincent.

Design and pre-press: Citizen Press – David Corvaisier, Hortense Lasbleis, Stéphane Boumendil.

Printing: Escourbiac l'imprimeur. ISSN 1283-9817.

Thanks to: Ursula Aniakou-Serrant, Sébastien Barde, Pierre Emmery, Pierre Le Metayer, Rémi Canton, Alexis Paillet, Sébastien Rouquette, Frank De Winne, Vincent Taponier, Isabelle Savin de Larclause, Pierre Guilhem, Jacques Arnould, Jessica Grenouilleau, Rebecca Billette de Villemeur, Romain Hernandez, Geoffroy de Broglie, Emmanuel Thulliez, Sophie Roelandt, Elodie Tran, Damien De Seze, Gérard Azoulay, Jean Blouvac.



10-31-1393

Horizons



“Destiny calls for Europe”

Lionel Suchet

CNES Chief Operating Officer

Human spaceflight today finds itself at the crossroads.

In engineering terms, the ISS has almost reached the end of the road, so it is only logical that we should now be looking at how to continue microgravity science and experiments in low Earth orbit when that day comes. In the current complex geopolitical climate, the announcements made at the International Space Summit envision a path for Europe in the shape of a cargo return service vehicle, a crewed capsule and launches from Kourou.

This political ambition must now be pursued through ESA by national space agencies at a time of budget restrictions. To this end, joint efforts to accomplish it will begin with the interim ESA ministerial conference in Rome at the end of the year, followed by the full ESA ministerial conference in 2028. And to play a meaningful part in international space exploration efforts, we need an affirmed yet realistic European ambition. These future human spaceflight endeavours are going to rely, among other things, on the expertise that CNES has developed over the last 50 years through the Hermes project, the ATV resupply vehicle, the CADMOS centre, the MEDES space clinic and parabolic flights operated by Novespace. You can read more about all of them inside this issue.

The space of the future will be shaped by the young people of today. So we are also counting on human spaceflight and its power to inspire and encourage them to take up careers in science in pursuit of their dreams, be they in space or not. Sophie Adenot's successful mission on the ISS will clearly go a long way towards achieving this aim, notably for the young girls that science so badly needs, as Claudie Haigneré's flight did 30 years ago.

PARTNERS

In this issue:

ESA - p. 6, 8, 14, 15, 16, 19, 20, 22, 24, 25, 26, 28, 29; SpaceX - p. 7, 15, 17; MEDES - p. 11, 20, 21, 24, 28; Novespace - p. 11, 21; DLR - p. 11; Blue Origin - p. 15; NASA - p. 15, 19, 22, 23, 26; Axiom Space - p. 15, 22; LISA - p. 17; Roscosmos - p. 19; Vast - p. 22; Starlab - p. 22; Safran - p. 24; ArianeGroup - p. 24; Airbus Defence & Space - p. 26; Toulouse University Hospital - p. 28; CNRS - p. 30; Lumetis - p. 30; BSPP - p. 31; Milan - p. 34; Printemps des Poètes - p. 34; French national military museum - p. 34

Conducting science from afar

From their control room, teams at the CADMOS centre for the development of microgravity applications and space operations are monitoring 30 or so experiments aboard the International Space Station (ISS), those developed by CNES and those for which the European Space Agency (ESA) has delegated responsibility. While some are fully automated, most require one of the station's crew to perform them—here Sophie Adenot—in line with the experiment's procedures drafted by CADMOS.





Live from Crew Dragon

———— **Cape Canaveral, 13 February, 11:15.** A SpaceX Falcon 9 soars skyward, sending the Crew Dragon Freedom capsule on its way to the ISS. Four astronauts are along for the ride: Americans Jessica Meir and Jack Hathaway (left), Russian Andrey Fedyaev (centre) and Sophie Adenot (right), the second French female astronaut in history after Claudie Haigneré. Sophie succinctly sums up the spirit guiding the mission: “Let’s dare to dream big together”.

Moonlight in Cologne

———— **A European astronaut on the Moon?** Not quite: this photo was taken in Cologne at ESA's LUNA facility inaugurated in 2024. This 700-sq.m. testing ground simulates all of the Moon's features—from lunar regolith, i.e. soil, to solar radiation and surface terrain—to better prepare for future missions there. The SpaceShip FR team has already used the facility several times to put concepts and prototypes through their paces for future human exploration missions, and to perform robotic mobility tests in a destructured environment.





The big white yonder as an analogue for isolation

————— **CNES doesn't wait to send astronauts into orbit to gain a deeper understanding of the effects of isolation on mind and body:** researchers overwintering at the French-Italian Concordia station in Antarctica offer comparable test subjects here on Earth. The agency has notably funded research at the station on sleep and pain, as well as on the psychological effects (depression, strained interpersonal relationships, stress, etc.) of prolonged periods in isolation.



EchoFinder, PhysioTool, EchoBones: monitoring health in space

During the eight-month *epsilon* mission on the ISS, Sophie Adenot will be conducting some 200 experiments, with seven new ones under the CNES banner. Conceived by the CADMOS centre for the development of microgravity applications and space operations and a broad network of scientific partners, three of the experiments aim to improve astronaut health monitoring. With EchoFinder, Sophie Adenot and her crewmates are performing ultrasound scans on one another, guided by augmented reality and artificial intelligence, without support from Earth. The device has been designed for future missions to the Moon or Mars, where communication lag times will preclude any guidance from Earth, and could also prove useful in medical deserts. For PhysioTool, Sophie Adenot's heart rate and blood pressure are being monitored by a small unit. PhysioTool is also exploring the impact of space on cognitive load through exercises on a tablet to test her concentration, decision-making and memory. Finally, EchoBones will employ pre- and post-mission bone imaging to measure the effects of weightlessness on the skeleton.



MatISS-4, MultISS and EuroSuit: keeping astronauts safe

Closely monitoring the ISS crew's health is important, but keeping them safe is equally so. Three of CNES's seven experiments on the *epsilon* mission aim to do just that. MatISS-4 is devoted to studying how bacteria respond to anti-microbial surfaces, using sensors placed inside units set up by Sophie Adenot in late April. The MultISS multispectral camera aims to identify surface bio-contamination that is invisible to the naked eye and can degrade essential equipment aboard the station. EuroSuit, on the other hand, is of a totally different nature: Sophie is testing a prototype intra-vehicular spacesuit to see how quickly it can be donned and removed in the event of a fire or depressurization.



ChlorISS seeding scientific reasoning

— In May, Sophie Adenot became a space gardener for ChlorISS, an educational experiment shared with more than 260,000 pupils in 4,500 schools across France, from 1st to 12th grade. The experiment is getting thale cress and mizuna seeds to germinate, then monitoring their growth daily for 10 days in the classroom and on the ISS. The aim is to observe the impact of microgravity, light and unexpected factors when handling the seedlings. Besides the exceptional nature of this common adventure, ChlorISS has given schoolchildren a unique opportunity to get to grips with scientific reasoning, teaching them how to formulate hypotheses, analyse data and prove—or disprove—their theories.



BRAHMS studies fasting in microgravity

In June, the MEDES space medicine and physiology institute conducted the BRAHMS (BedRest And HypoMetabolism) clinical study to examine the combined effects of fasting and microgravity, simulated by prolonged bedrest. For the study, ten male subjects aged 20 to 40 spent ten days in a bed tilted back six degrees so that their head was slightly below their feet and were restricted to a daily intake of 250 kilocalories. The results are now in: the subjects exhibited muscle and bone loss, as well as a redistribution of bodily fluids. Such physiological effects are comparable to those observed in astronauts in weightlessness. Adding fasting to the experiment protocol enables researchers to gain a deeper insight into the consequences of being deprived of food in space in the event of a failure of the life support system, a break in food supplies or a mission extension.

Microgravity science for 71st parabolic flight campaign

Operated by CNES's subsidiary Novespace out of Mérignac airport, the Airbus A310 Air Zero-G is a fully fledged microgravity research laboratory. Every year, CNES, ESA and the German space agency DLR take turns to organize scientific flight campaigns on the aircraft. For CNES, the 71st such campaign got underway in September, carrying 12 experiments in the fields of material and life sciences—three flights over three days, flying 90 parabolas to explore fluid physics applied to blood flow, the antiseptic potential of cold plasma and fire propagation aboard spacecraft.

One day all lunarians?

The Moon has always held a fascination for humans, who dream one day of settling there. Between a utopian vision and concerned realism, cinema, literature, music and video games are constantly exploring our nearest neighbour, which enthral us and is maybe more like us than we think.



Round and golden, it appears almost within reach. So close that it has always fuelled our wildest dreams. And one of the most ancient records of this fascination is... a rabbit! Many cultures in Asia, South America and Africa recount legends evoking a lunar rodent that supposedly spends its days baking cakes and

preparing love potions or health remedies. Most likely due to a pareidolia¹ effect, as some dark patches formed by the Moon's maria could indeed be seen as a rabbit, these founding tales have spawned many a story. As early as the second century of the Common Era, Lucian of Samosata imagined in his *A True Story* the Selenites, a lunar people resembling humans. 1,500 years later, Galileo discovered that our natural satellite has relief similar to Earth, fomenting the fantasy that it might be habitable. Numerous authors subsequently latched on to the idea. One of the first was Cyrano de

Bergerac, who in his *The Other World: Comical History of the States and Empires of the Moon* (1657) depicts a hero who reaches the Moon in a



flying machine with rockets and discovers a flourishing civilization. Jules Verne (*From the Earth to the Moon*, 1865) and Hergé (*Destination Moon*, 1953) would later mine this same seam, sowing the seeds of an imaginary realm that has inspired generations of engineers.

Hopes and fears

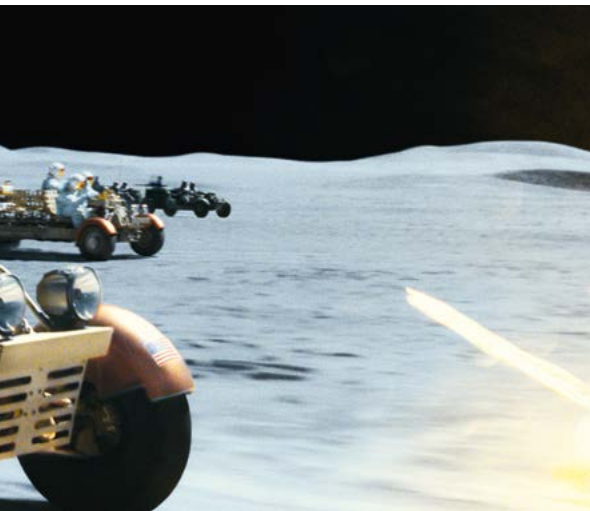
With advances in science and technology, the idea that humans may one day actually settle on the Moon is firing passions. But lunar fiction has adopted a perspective of concerned realism rather than wonder. In the world of movies, *Tykko Moon* (Enki Bilal, 1996) portrays a Moon long colonized that has become a dirty, dusty den of inequality beset by power struggles. *Moon* (Duncan Jones, 2009), meanwhile, features a lone man tasked with maintaining a helium extraction base. Ten years





later, *Ad Astra* (James Gray) explores a militarized Moon fiercely disputed by powers with conflicting interests. The *Deliver Us the Moon* (2019) video game further probes this dark vein, as the player explores an abandoned lunar base in a future where Earth's resources have been depleted and humankind has put all its bets on exploiting the Moon before losing everything—the Moon as a last-chance saloon or final warning for Earthlings. Yet hope remains, and with it some light relief. This is best reflected in music: Police's *Walking on the Moon* (1979) celebrates weightlessness as a promise of freedom, while in *Moon Safari* (1998) and then *Le Voyage dans la Lune* (*A Trip to the Moon*, 2012), the soundtrack to the colourized version of Méliès' film, French band Air compose a sleek, strange and yet surprisingly inviting world. And Amel Bent, in *Ma Philosophie*, sees it as a metaphor for emancipation. The line "Viser la lune, ça ne me fait pas peur" (I'm not afraid to shoot for the Moon) marked a generation, reminding us that here on Earth or 384,400 kilometres away, there's still room to dream.

1. A natural tendency to see familiar patterns in random shapes.



Insights

Alexis Paillet,

SPACESHIP FR PROJECT LEADER



"Crews will have to supervise themselves"

Is it conceivable that anyone could live on the Moon in the future?

As things stand, that's unlikely to happen. Settling on the Moon is complicated by the distance and our limited lift capability, under 10 tonnes even in the most ambitious case. The model we're working on at SpaceShip FR is a base where four people would live autonomously for six months, inside a very confined underground habitat. So it's not for everyone!

What would we eat on the Moon?

We're aiming to achieve a mixed diet, based on freeze-dried products and plants grown in situ, with almost every part edible. For animal protein, we're looking at farming fish in an aquarium so residents could see them swimming around, which would lift their spirits. But then we're not sure they'd want to eat them anymore! That's one of the seemingly unlikely questions we need to address.

What would be the fundamental differences between settling on the Moon and on Mars?

The main difference is the distance and everything that implies. For Mars, we're talking about a 20-minute communication lag and even a month-long black-out when it passes behind the Sun. So the mission has to be fully autonomous. For the Moon, the lag is just three seconds, so we can still rely on ground teams here on Earth. But the conditions are harsher, as there's no atmosphere and the temperatures are extreme. Mars is more like Earth, but getting there is another matter!

Leading light

FRANK DE WINNE

Head of LEO Exploration Group and Europe exploration
programme implementation at ESA's Human and Robotic
Exploration directorate



**“Europe must reinvent itself
and find its place in
international cooperation”**

Former test pilot, astronaut and the first European to command the International Space Station, Frank De Winne has seen up close the major shifts the space sector has undergone. He analyses for us the challenges facing Europe as it seeks to strengthen its space sovereignty in a fast-changing geopolitical context.

_____ You've been involved with human spaceflight for more than 25 years. What big changes have you seen in that time?

The biggest transformation has been the growing role of the private sector. Before, everything related to infrastructures and transportation was handled by the world's space agencies. Today, contractors are taking on more responsibility in developing, certifying and configuring launch vehicles and spacecraft. We're seeing this not only with SpaceX, but also Blue Origin or the new spacesuit designed for NASA by Axiom Space for crewed flights to the Moon. The same shift is occurring in scientific research. At ESA, 30% of our resources dedicated to research are supporting commercial projects. Looking ahead, we'll also see orbital stations operated by private players.

_____ In 1991, you were selected for the Hermes programme before it was shelved. What's your perspective of this chapter of European space history?

Hermes was a crewed space shuttle project designed to give Europe independent access to space and enable it to do microgravity science. As a test pilot at the time, I worked on the human-machine interfaces. The programme was halted and today Europe is the only major space power without independent access to space for its astronauts. This leaves us at a huge disadvantage compared to China, the United States and Russia, and also to India, which is developing such a capability.

_____ What challenges is the Old Continent facing now to build its own exploration capability?

In low Earth orbit, the priority is to continue getting the most out of the ISS and to develop a European LEO cargo return service capability. Europe must rekindle

“Europe must rekindle the ambition to possess its own capability to send astronauts into space.”

the ambition to possess its own capability to send astronauts into space. The Argonaut lander will take science and technology to the lunar surface. To sustain operations on the Moon in the long term we need to develop robotic mobility and dexterity, and to invest in renewable sources of energy to survive for two weeks of lunar night, as well as in navigation and communication systems. And to give European astronauts the chance to set foot on the Moon, we must continue working with NASA on the Artemis programme.

_____ What impacts is the current geopolitical climate having?

Our relationship with the United States has become much more transaction-driven than before. The Lunar Gateway project has been put on hold and Mars Sample Return revamped and then shelved. In this context, Europe needs to reinvent itself and find its place in international cooperation, which remains a pillar of space exploration. It must develop its own capabilities and no longer be dependent on others to accomplish its programmes. Our astronauts and agencies have the expertise to do this, but we need the political will to secure the funding required to develop such systems. This is the debate we'll be having with our member states later this year at the International Space Summit and the ESA Interim Council meeting at Ministerial level.



2000

Joins ESA's astronaut corps.

2002

Embarks on OdISSea mission on Soyuz capsule.

2009

First European astronaut to command ISS.

2012

Becomes Head of European Astronaut Centre in Cologne.

2023

Head of implementation of ESA's ISS and Terra Nova programme.

“We need the political will to secure the funding required to develop such systems.”

_____ What can astronauts do that machines will never be able to do?

That's a constant question for us humans. We like to explore places and go where it's hard to go, to do things robots can't. Purely robotic exploration has its limits. Crewed missions spur innovation and are a source of inspiration for us, especially for youngsters.

_____ You helped to develop the European Columbus laboratory module for the ISS. Why is microgravity science still relevant in 2026?

In space, microgravity affects all results, whether we're researching astronaut metabolism, plant behaviour or how foams react in weightlessness. More and more research scientists are using the ISS,

and more and more commercial companies are seeing the value of doing research in microgravity. This unique domain can help us to gain new insights to improve processes, accelerate development of new medicines and materials, and seek solutions to adapt to climate change. I believe research in microgravity is only just getting started.

_____ In 2009, you became the first European to command the ISS. What did you learn from that experience?

It was a huge honour and a privilege to be the ISS commander. On the station, it's the commander's job to make sure the crew can work efficiently and in the right conditions to perform all the tasks assigned to them. Crewed missions rely above all on the teamwork with the engineers, technicians and scientists on the ground.

pointers



Crewed capsule or spaceplane: What's the difference?

— In the world of human spaceflight, there are two main complementary concepts: capsules and spaceplanes (or shuttles).

- A capsule is conical or spherical in shape, trading simplicity for reduced manoeuvrability. It lands by parachute. Unlike the first models, modern capsules like Orion or Crew Dragon are designed to be reused with a new heatshield.

- A spaceplane, as its name suggests, has wings that allow it to manoeuvre in the atmosphere and land on a runway. It also has the advantage of subjecting the payload or crew to lower levels of acceleration, at 2 or 3g, far less gruelling than when re-entering the atmosphere in a capsule. On the other hand, its wings are of no use outside low Earth orbit. The capsule currently remains the best solution for exploring the Moon or Mars.

1. Two to three times higher than that experienced due to gravity.



10.8 km/s

**The speed
a spacecraft**

must attain to be injected into lunar transfer orbit (LTO). It then decelerates naturally until it arrives near the Moon, where a final braking thrust inserts it into low lunar orbit at a speed of around 1.6 km/s.

EMA is back

On 27 February, SpaceX's Dragon CRS-33 resupply spacecraft splashed down in the Pacific, bringing back with it the French EMA experiment. Prior to its return, EMA had spent a whole year attached to the Bartolomeo external payload platform on the ISS. Here, its two payloads—SESAME (CNES) and IR-COASTER (LISA inter-university laboratory for the study of atmospheric systems)—were continuously exposed to the vacuum of space and solar radiation. Their mission was to study the ageing of new materials and the effect on astrobiology samples of being exposed to space. Back on French soil, EMA was delivered to CNES where it was dismantled and subjected to a first series of health checks. IR-COASTER was then returned to LISA to pursue the experiment, while SESAME will stay at CNES to compare the properties of materials before and after this sojourn in space to inform the design of future orbital systems.

Human spaceflight and exploration: decision time for Europe

With the International Space Station nearing the end of its operational life and Artemis ramping up, human spaceflight is entering a new era. As they seek greater independence and new partnerships, Europe and France are reshaping their strategy.

The International Space Station's solar arrays, photographed during the extra-vehicular activity conducted on 18 March 2026 by Jessica Meir and Chris Williams.





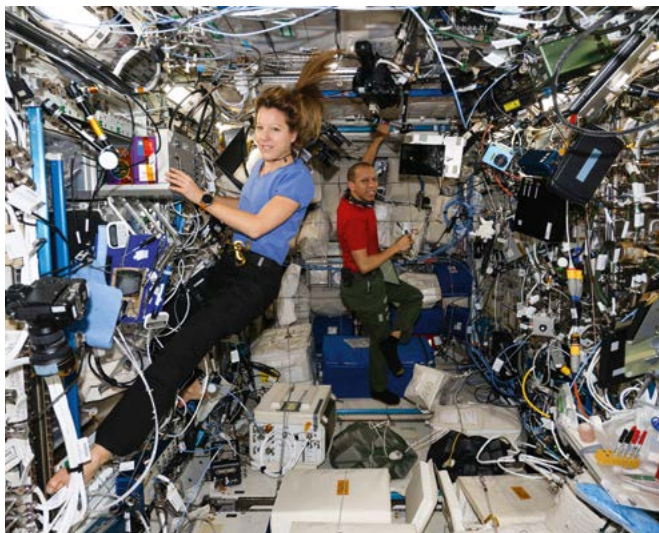
European space at the crossroads

For decades, Europe's human spaceflight and space exploration programme has been built on partnerships, first with the Soviet Union and then with the United States. Today, the playing field has shifted and Europe must decide what degree of independence it desires.

————— **Europe's human spaceflight programme is the result of a concerted decision.** In 1998, the continent's leading space nations—Germany, Italy and France—folded their national astronaut corps into a single European corps, stationed in Cologne. From this moment on, its space exploration efforts would continue under the common banner of the European Space Agency (ESA).

On 20 November of the same year, the first elements of the ISS were dispatched into low Earth orbit. It would take 11 more years to assemble the 74-metre-long structure and its 400 m³ of living quarters. The station comprises two separate parts: the Russian segment built and operated by the Russian federal space agency Roscosmos, and the United States Orbital Segment (USOS) built and operated by NASA, with contributions from the Canadian and Japanese space agencies and ESA. "This segment is like a co-owned property," explains Sébastien Barde, head of CNES's Exploration and Human Spaceflight sub-directorate. "Each agency's share of the station is in proportion to their contribution (see box). Europe's share is 8.6%, so we're assigned 8.6% of the crew's time, communications bandwidth and payload mass on each mission. The United States' share is 76%."

This arrangement gives Europe access to a unique laboratory in microgravity that it could never have funded alone. "We do two types of science aboard the station," says Sébastien Barde. "First, fundamental science like material physics, for example, which takes



ESA astronaut Sophie Adenot and NASA crewmate Chris Williams inside the Columbus laboratory module on the International Space Station.

advantage of the effects of microgravity to observe phenomena masked by gravity on Earth. And second, life sciences like physiology and medicine to gain new insights into how the human body responds to these effects.” Life science research aboard the ISS is also feeding into work being conducted by European partners in preparation for space exploration missions. This theme is gaining prominence and is a focus for several teams at CNES, like the CADMOS centre for the development of microgravity applications and space operations, the MEDES space medicine and physiology institute or Spaceship FR, which aims to be a precursor for a future lunar and/or Martian base, combining technologies developed in France. Through ESA, CNES is also involved in major space exploration programmes like the European Argonaut lunar lander or the European Service Module (ESM) for the Artemis programme’s Orion crew vehicle.

Taking stock

But this balance is looking increasingly precarious. “In space exploration, Europe depends closely on its relationship with the United States,” notes Pierre Emmerly, CNES’s delegate to ESA for space exploration affairs. “This can cause difficulties, notably when they take unilateral decisions that may have huge financial

and strategic consequences for Europe. This has proven the case for the Mars Sample Return programme in the past and Artemis¹ today. What’s more, with the Trump administration space exploration is once more being driven by political ambitions with nationalistic undertones.” And above all, a hiatus is looming with the scheduled decommissioning of the ISS by 2032 and the suspension of the Gateway² project, to which Europe was set to make a major contribution, supplying half of its envisioned modules, for which new missions now need to be found. “So the three key destinations driving space exploration efforts—low Earth orbit, the Moon and Mars—are now all in doubt,” says Sébastien Barde.

For France and CNES, the road ahead can be summed up in one word: autonomy. “France has always pushed for greater sovereignty,” affirms Pierre Emmerly. “But budget constraints limit its funding, while other member states remain closely tied to Washington.” At ESA’s human spaceflight, microgravity and exploration programmes committee, a strategic approach is taking shape predicated on conceiving each investment in a new project so that it still has utility, whatever happens. “These are difficult times, but it’s also an opportunity for Europe to take its destiny into its own hands,” notes Pierre Emmerly. It is with this purpose in mind that at the Space Summit organized by France in September, ESA’s member states approved a declaration stepping up Europe’s ambitions in space exploration, ahead of the Interim ESA Council meeting at ministerial level in December 2026.

¹ NASA programme to establish a permanent human presence on the Moon.

² Cislunar station project (orbiting within the vicinity of the Moon).

Barter is the word

————— No money changes hands between the ISS partners. The partnership model is built on a barter system in which each partner provides hardware or services—like the ATV resupply vehicles or the Columbus laboratory for Europe—and in return granted access to ISS facilities in proportion to their contribution.

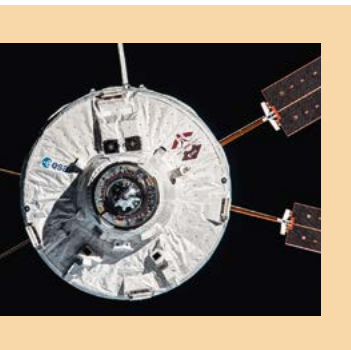




From left: Haven-1 space station (Vast Space); Axiom Space; Starlab Space station.

Human spaceflight after the ISS

Maintaining a presence in crewed space missions once the ISS has been phased out is the challenge that now faces France, which is advancing its pawns and exploring all avenues with pragmatism and ambition.



——— **Thanks to CNES and its partners**, France has developed world-class expertise in human spaceflight over more than 40 years. CADMOS, MEDES and Novespace³ are precious resources providing logistic and operational support for microgravity science. “But with the ISS set to be phased out between 2030 and 2032, France and Europe need to rethink their

human spaceflight and microgravity science strategy,” says Pierre Le Metayer, who heads CNES’s space exploration and human spaceflight programme. “The decommissioning of the ISS is going to stall the efforts of the scientific community and the entire value chain behind each astronaut.”

———— **Three avenues are envisioned.** Through its Commercial LEO Destinations (CLD) programme, NASA has chosen to transition from the ISS to orbital stations built and operated by private contractors like Vast, Axiom and Starlab. In Europe, several scenarios are on the table. The first would look to develop its own independent space station. This avenue is currently being studied by ESA, but the prospective costs are huge and a consensus between member states will be hard to achieve. The second would involve working with legacy ISS partners Canada and Japan, or with emerging space powers like India and the United Arab Emirates. But this kind of architecture assumes sustained political and industrial convergence. As an alternative to these more long-term visions, a third pragmatic and opportunistic path now emerging would seek to forge agreements with private station operators. This is the path France has chosen in signing an unprecedented contract with Vast. In 2027, Thomas Pesquet will command a mission managed by the company on the ISS, and a few months later Arnaud Prost will become the first French astronaut to fly on a private station, Haven-1, on a first-of-its-kind test mission, and the first Euro-



Astronauts Arnaud Prost and Thomas Pesquet are set to fly on commercial space missions for U.S. firm Vast.

pean astronaut to be involved in qualifying a space station.. CNES will be tasked with preparing, operating and monitoring the two astronauts’ activities alongside all the other stakeholders. “This investment could open up new post-ISS horizons, notably by fostering relationships with private players,” notes Pierre Emery, CNES’s delegate to ESA for space exploration affairs. “For example, we could imagine partnerships based on the same rationale as ISS barter arrangements (see box p. 20), with services provided in return for astronaut seats, while maintaining our cooperation with ESA, which remains the bedrock for space exploration missions.”

³ CNES subsidiary specializing in parabolic flights.



———— **“Being able to do science in microgravity is a great opportunity for the scientific community, particularly to study living organisms in space and obtain possible spin-offs. In the post-ISS era, CNES will continue to act as the go-between for the French scientific community to take advantage of flight opportunities, while working alongside the member states to chart ESA’s strategic roadmap.”**

Pierre Le Metayer

3

**Minimum number
of European
astronauts**

making up the crew of Vast's
PAM-1 mission, including
Thomas Pesquet.

Artemis takes a European turn

**Europe and France are advancing their
assets for the United States' major lunar
programme, from the technical core of
Orion to its cockpit.**

———— In December 1972, Gene Cernan and Harrison Schmitt spent some 75 hours scouting on the surface of the Moon during the Apollo 17 mission—the longest sojourn on our natural satellite, and also the last to date. With the Artemis programme initiated by NASA in 2017, crewed lunar exploration is set to embark on a new chapter, with the aim at the start of the next decade of establishing a permanent base. But the road to that point remains a long one. Last April, the Artemis 2 mission accomplished the first crewed flight of the Orion spacecraft. Next year, Artemis 3 will test Orion's ability to dock with a lunar lander in Earth orbit, as the final stage before taking a crew back to the Moon in 2028 on Artemis 4.

Astronaut Harrison H. Schmitt collects samples from the Moon's surface on 12 December 1972 during the Apollo 17 mission.



The Orion spacecraft stands atop NASA's Space Launch System (SLS) rocket prior to launch on the Artemis II mission.

What role are Europe and France set to play in this highly symbolic, scientific and geopolitical adventure? ESA is supplying the European Service Module (ESM), a key element that will provide Orion with vital functions for its journey, namely power, propulsion, thermal control, air and water. France is contributing several critical systems to the ESM, including gas filtration systems produced by Safran, fuel and helium tanks by ArianeGroup and the avio-

tics systems and wiring harness. Artemis 2 was also carrying another French passenger in EveryWear, a health monitoring application developed by CNES able to transmit the crew's physiological data to ground. On the astronaut side, Europe is also well represented. In early June, Luca Parmitano was announced as Orion's pilot for Artemis 3, a privileged position confirming that the lunar adventure is still alive and kicking on this side of the Atlantic.

Mars almost for real

— The Moon is a stepping stone to Mars. It was with this prospect in mind that teams from SpaceShip FR—a European initiative laying the groundwork for space exploration and crewed space missions—and MEDES spent a few days in the simulation facility at Toulouse University Hospital to conduct science, maintenance and sporting activities in conditions replicating those on Mars. The aim was to collect precious data to assess the feasibility of a future crewed mission to the red planet.





Concept study of a human-rated version of Ariane 6, with a crew transport capsule.

Lunar pathways

Getting to the Moon—or Mars—and back requires the right resources on the ground, powerful recoverable launchers and special spacecraft.

So it's no surprise these are three main fields of investigation CNES is pursuing for space exploration and crewed spaceflight.

On the ground, ESA has entrusted CNES with a study to adapt the Guiana Space Centre (CSG) with a view to qualifying Ariane 6 for crewed space missions. Three infrastructures are being looked at: the first would be a building to house and quarantine crews, as well as a hall to accommodate a crew capsule, launch abort system and other spacecraft elements. Ariane 6's launch complex is also expected to evolve to install a crew access arm equipped with an emergency escape slide. At the same time, to launch a capsule in the same class as Orion weighing 15 to 25 tonnes Europe would need to develop its own super heavy launcher. With the ASTRE project, CNES is federating upstream research and technology

demonstrators to ready an engine capable of delivering 200 to 300 tonnes of thrust—against 100 to 130 tonnes on the current generation of launchers—within a timeframe of five to ten years. On the spacecraft front, ESA is leading the LEO Cargo Return Service programme (LCRS) that plans to develop a reusable successor to the ATV transfer vehicle, initially to ferry cargo to low Earth orbit but with the potential to evolve towards crewed space missions or lunar resupply. To support this project, CNES undertook a preliminary project in house to gain an independent view of its value and feasibility. This project's findings helped inform France's decision to include its contribution to the development of this European resupply craft in its national 2025-2040 space strategy.

What comes after Ariane 6?

CNES and its partners are pursuing a series of preliminary project studies on a successor to Ariane 6, all of them exploring a reusable first stage and methane propulsion. But no architecture has yet clearly emerged as the winner: from continuing with an Ariane 6-class launcher to a super heavy lift option, the spectrum of solutions remains open in a sector where a multitude of players are in increasingly close competition.



Back to the future

From Hermes to Orion: a European human spaceflight odyssey

Thirty years of space engineering have seen Europe pursue three programmes with a common ambition. We look back at this enduring adventure that started with a project to build a spaceplane that finally did not materialize and is now poised to take Europe to the Moon, providing vital support functions for the Orion capsule.



Artist's depiction of the European Hermes spaceplane project developed by CNES.

MILESTONES

1977

CNES kicks off studies for Hermes

1992

ESA cancels Hermes project

2008

First flight of ATV resupply spacecraft

2018

First ESM delivered to NASA for Artemis I mission

April 2026

During the Artemis II mission, the Orion capsule accomplishes a 10-day voyage in the vicinity of the Moon

Our story begins in the 1980s.

"Riding on the crest of a newfound political will, Europe set out to gain access to space with its own crews and spacecraft," notes Sébastien Barde, head of CNES's Exploration and Human Spaceflight sub-directorate. "The Hermes spaceplane project led by CNES crystallized this ambition." Industry really got behind this project in a big way, generating major advances across many domains, but the Challenger¹ disaster would prove a fatal blow, as costs spiralled and the schedule slipped inexorably away. In 1992, ESA put the project on hold before cancelling it altogether. But the acquired expertise—in autonomous guidance, in propulsion and avionics—remained and was reinvested in the Automated Transfer Vehicle (ATV) programme to resupply the International Space Station with water, oxygen, fuel and science equipment. Five of these jewels of technology capable of performing approach and docking manoeuvres autonomously would subsequently fly between 2008 and 2014, piloted from the ATV control centre at CNES in Toulouse. This success secured Europe's place in the crewed space exploration landscape. Now, 12 years after the last ATV flight, the legacy of Hermes lives on through the European Service Module (ESM) for NASA's Orion capsule. Developed by Airbus Defence & Space, the ESM provides essential support functions—water, air, power and above all propulsion—to the spacecraft, which accomplished its first crewed flight last April. "Its distinctive cross-shaped solar arrays are derived from the ATV's design," points out Sébastien Barde. "Without the ESM, Orion could neither reach lunar orbit nor return to Earth."

¹ In 1986, the U.S. Space Shuttle Challenger broke apart shortly after lift-off, claiming the lives of its crew of seven astronauts.



Jacques Arnould

Science historian and theologian, CNES ethics officer

The crow, the fox and the grapes

“Fable is the elder sister of history,” wrote Voltaire. And what if we revisited the human spaceflight saga through the prism of La Fontaine’s *Fables*?

——— **Their names were Laika, Sam and Hector**, and they paved the way to space for Yuri, Neil and Jean-Loup. In the early years of the space era, engineers and scientists were in the habit of naming these animals sent into space. It’s a shame they didn’t just call them the Dog, the Monkey and the Rat, otherwise their adventures might have inspired a descendant of Jean de la Fontaine to write fables examining how we do things in space today. But we don’t have a space fabulist to hand, so we must content ourselves with the fables of the famous 17th century writer to peruse the 65 years that have elapsed since Gagarin’s flight.

The Fox and the Crow obviously brings to mind the first decade of the space era, when two nations had exported into space the Cold War they were waging. Following a string of successes, failures, rousing announcements and closely guarded secrets along the way, the cheese, i.e., the man on the Moon, was passed from one beak and mouth to another in the hope of being awarded the title of phoenix of space... In the end it was Sam who came out on top. The moral of *The Frog and the Ox* could be applied to many a space project, such have hubris and excess

often been evident on the launch pad. Conversely, the Hermes spaceplane adventure was nipped in the bud before a possible “explosive” ending, without compromising future successes in space for Europe riding on the wings of Ariane. Could it be that the country that dines on frog’s legs, where a model of the spaceplane is still preserved, encouraged the rest of the European community to heed the fable’s moral? Maybe Apollo 13 wasn’t the only “successful failure” after all.

All of which brings us to the new Moon race, this time between the United States and China. A journalist writing for the *Tribune de Genève* in June 2024 dared to compare it to the American hare and the Chinese tortoise, a fine tribute to one of La Fontaine’s most celebrated fables. However, this race is far from over and we know that space has never missed an opportunity for us to say “goodbye calf, cow, pig, brood” (or don’t count your chickens before they’ve hatched)!

But let us return to our friend the fox and a short yet acerbic fable, *The Fox and the Grapes*. Should it be applied to Europe’s prevarication on the subject of Moon and Mars projects? Are the fruits we covet really sour or do they simply look unripe from the perspective of our pale ambitions and lack of resources? Aesop’s verdict is sterner: “It is easy to despise what you cannot get”—an invitation to contemplate what kind of glory we desire.



MEDES

"Crewed spaceflight can't exist without research on humans in space"

**REBECCA BILLETTE
DE VILLEMEUR**

Head of Clinical Research, MEDES

——— **"Space grabs you unexpectedly and soon becomes a passion. You feel part of the great human adventure,"** confides Rebecca Billette de Villemeur. At medical school she specialized in public health, while also obtaining a master's degree in epidemiology and clinical research. As a junior doctor she worked night shifts at the MEDES space medicine and physiology institute at Toulouse University Hospital. "I knew I wanted to do clinical research, but I got involved with space medicine somewhat by accident," she recounts. During her shifts, she developed a keen interest in physiological mechanisms, studying them from all angles, at the molecular and organism level. On completing her training as a junior doctor in 2020 her first posting was with MEDES, and two years later she became its Head of Clinical Research. "My job is to look after the volunteers taking part in our studies." Here, the medical team conducts bedrest campaigns for CNES and ESA, which replicate the state of prolonged weightlessness that astronauts experience in space. MEDES

assesses the technical and ethical feasibility of scientific protocols, and once an experiment has been validated by the health authorities recruitment of volunteers can go ahead.

"Candidates go through a series of tests and we select those who most closely match our criteria for inclusion in the study: they must be aged 20 to 45, physically fit and in perfect health." In 2023, Rebecca Billette de Villemeur led the BRACE study to test "if artificial gravity with a centrifuge arm enhances the benefits of exercising on a bike", to counter the negative effects of microgravity on the human body. "The 24 subjects were in a bedrest position for 60 days. In that time, you really do get attached to people!" Another method that MEDES uses to simulate weightlessness is dry immersion, where the volunteer is placed inside a waterproof fabric immersed in a bath filled with warm water. The body thus feels as if it is floating. In the years ahead, MEDES will be focusing on the effects of lunar missions like Artemis. "To find ways of preserving astronauts' health and performance, we need to conduct studies here on the ground. MEDES wouldn't exist without CNES and crewed spaceflight can't exist without research on humans in space," stresses Rebecca.



ESA

"Member states are giving themselves the ability to move towards crewed missions"

JESSICA GRENOUILLEAU

Coordinator of pre-development studies for lunar missions and human spaceflight, ESA

_____ "My aim is to contribute to innovative projects pushing the boundaries of space exploration and technology," explains Jessica Grenouilleau, an engineer specializing in aerospace system maintenance, with ESA since 1996. She contributed to the development, commissioning and handling of operations for the Columbus orbital laboratory, and helped to qualify the Automated Transfer Vehicle (ATV) that flew resupply missions to the ISS. In 2015, she moved to the Netherlands to work on robotic exploration at the agency's European Space Research & Technology Centre (ESTEC). In 2023, Jessica Grenouilleau was appointed to coordinate pre-development studies

for lunar missions and human spaceflight. Russia's invasion of Ukraine has since left the western world's space industry in turmoil, while the twists and turns of U.S. policy are compounding uncertainties. Navigating a path between cooperation and competition, Europe is seeking to strengthen its independence and autonomous access to space. This involves developing new capabilities like the LEO Cargo Return Service (LCRS) programme. "With LCRS, member states are giving themselves the ability to move towards crewed missions. All nations that have succeeded in doing this started out with cargo missions," notes Jessica. Now in charge of the launch abort system designed to pull the crew away from the launcher in the event of a serious anomaly, she's working closely with CNES to adapt launch facilities at the Kourou spaceport. Looking beyond low Earth orbit, Europe is gearing up to go to the Moon with its future Argonaut lander. "From Earth's nearest celestial neighbour, we can observe the universe in much finer detail and peer back in time to gain new insights into how it came into being and formed," says the engineer. But the lunar environment is harsh, with its extreme temperatures, difficult lighting conditions and corrosive dust. "Deep-space exploration, like exploring the most extreme conditions on Earth, is leading us to develop survival techniques and technologies." For a while, Jessica Grenouilleau could in fact see herself as an explorer in the Antarctic when she was working on her PhD at the Ecole Centrale engineering school in Paris: "the Paul-Emile Victor polar institute (IPEV) offered me the chance to go to the Dumont-d'Urville¹ research station on a one-year rotation, but life decided otherwise."

for lunar missions and human spaceflight. Russia's invasion of Ukraine has since left the western world's space industry in turmoil, while the twists and turns of U.S. policy are compounding uncertainties. Navigating a path between cooperation and competition, Europe is seeking to strengthen its independence and autonomous access to space. This involves developing new capabilities like the LEO Cargo Return Service (LCRS) programme. "With LCRS, member states are giving themselves the ability to move towards crewed missions. All nations that have succeeded in doing this started out with cargo missions," notes Jessica. Now in charge of the launch abort system designed to pull the crew away from the launcher in the event of a serious anomaly, she's working closely with CNES to adapt launch facilities at the Kourou spaceport. Looking beyond low Earth orbit, Europe is gearing up to go to the Moon with its future Argonaut lander. "From Earth's nearest celestial neighbour, we can observe the universe in much finer detail and peer back in time to gain new insights into how it came into being and formed," says the engineer. But the lunar environment is harsh, with its extreme temperatures, difficult lighting conditions and corrosive dust. "Deep-space exploration, like exploring the most extreme conditions on Earth, is leading us to develop survival techniques and technologies." For a while, Jessica Grenouilleau could in fact see herself as an explorer in the Antarctic when she was working on her PhD at the Ecole Centrale engineering school in Paris: "the Paul-Emile Victor polar institute (IPEV) offered me the chance to go to the Dumont-d'Urville¹ research station on a one-year rotation, but life decided otherwise."

¹ French research station in the Antarctic, on Petrel Island, Adélie Land.

LUMETIS

"CNES helped us to space-rate our technology"

ROMAIN HERNANDEZ

PhD in optics, Lumetis

———— **"Housework" aboard the ISS** involves rooting out micro-organisms that can damage critical equipment, a risk first identified in the 1980s by the crew of the Mir space station. "In microgravity, bacteria and moulds proliferate on surfaces everywhere, forming biofilms that can attack control panels and jeopardize crew health," explains Romain Hernandez. In 2023, this research scientist specializing in photonics¹ left the French

national scientific research centre

CNRS to join imaging start-up

Lumetis. Recruited for his

qualifications in optics, he

set about developing a

tool capable of detecting

these threats that are

invisible to the naked

eye. Working with the

CADMOS centre for the

development of

microgravity applications

and space operations, the

unit at CNES devoted to crewed space exploration, Lumetis conceived MultiISS, a multispectral camera that illuminates surfaces in ultraviolet, visible and infrared wavelengths to reveal the presence of bacterial biofilms or moulds. The challenge is to identify biological contamination and target areas that need to be cleaned to preserve the crew's health and prevent corrosion. "For three years, CADMOS helped us with its expertise in crewed spaceflight to space-rate our technology. Equipment manufacturer Comat supported us on safety aspects," says Romain. Here on Earth, multispectral imaging has already found spin-offs. In the art world, it can reveal pentimenti and alterations in a painting. But that's not all: it also assists surgeons, aids traceability of sensitive military components and makes production lines safer, for example. "We've also worked with an archaeology PhD student who's studying how the paintings in the Chauvet Cave could have been protected by a calcite veil for so long," he notes. For the SpaceShip FR innovation laboratory led by CNES, Romain Hernandez is working on GeoAssist, a prototype geologist's assistant capable of helping an astronaut or robot to analyse rocks and collect samples. "It's the same technology, only going further into the infrared up to 1.7 microns to better reveal rock details," he explains. "The ultimate aim is to hitch a ride on upcoming flights to Mars or lunar missions like Artemis."

¹ Sciences and technologies that generate, detect or manipulate light.

BSPP

"Testing out equipment developed for deep-space crewed missions"

GEOFFROY DE BROGLIE

Deputy Chief of BSPP's design and foresight office



9 March 2008, Kourou launch base: an Ariane 5 is all set for lift-off. Under its fairing, the ATV Jules Verne, Europe's first cargo resupply spacecraft. The 3rd foreign infantry regiment has secured the launch zone. Platoon leader Geoffroy de Broglie is one of them. In two years in French Guiana, he had been deployed for 11 launches, but this one in particular left a lasting impression "because of the launcher's size, which meant we had to double the safety perimeter, and the deafening noise when it lifted off". On returning to mainland France he was assigned to the Paris fire brigade (BSPP) at Ménilmontant fire station and then as commander of the 24th fire and rescue company in Montreuil, outside Paris. After a year studying for a master's degree at the CentraleSupélec engineering school, Geoffroy de Broglie managed weapons programmes for the

French Army before rejoining the ranks of BSPP. Appointed as deputy head of the brigade's design and foresight office in 2023, the lieutenant-colonel is preparing it strategically and technologically for the challenges that lie ahead. His missions are "to identify the major changes to our environment, prefigure new equipment, increase operational safety and work to make us more resilient," he says. It is on this basis of continuous innovation that BSPP and CNES signed a unique partnership agreement in June 2025 to pursue the shared ambition of accelerating development of cutting-edge technologies. The military and space domains both have to contend with the same challenges of operating in extreme conditions, guaranteeing the reliability of equipment, maintaining communications, handling stressful situations and ensuring that firefighters are physically and mentally fit. "Space and fires are both environments where losing your bearings generates a lot of stress that has to be controlled," underlines Geoffroy de Broglie. For autonomous robotics or miniaturization of medical tools, the combination of firefighters' operational know-how and CNES's space expertise is a "lever for innovation". And for Geoffroy de Broglie, the BSPP can be "a full-scale laboratory for testing out equipment developed for deep-space crewed missions". This year, firefighters will be testing the ability of spacesuits to withstand fire in real conditions. By then, the lieutenant-colonel will have joined the 1st fire and rescue brigade to defend the capital and its outskirts. "Being part of the space adventure is a great source of pride," he concludes.

Stepping stones

Space experiments, from drawing board to data

The lifecycle of a space science programme, from choosing experiments for a crewed spaceflight to extrapolating their results on Earth.

Crewed missions start long before lift-off, their scientific content being developed on the ground with support from the CADMOS centre for the development of microgravity applications and space operations.

Programme design



Proposals submitted by the scientific community are selected for their science value, maturity and feasibility. In the case of epsilon, they relate to human physiology and future space technologies, as well as education with ChlorISS¹ (see Space take, p.10).

¹ Educational experiment to understand the effects of light on plant growth.

To adapt them to the constraints of the ISS and ensure the crew's safety, hardware and software needed to conduct experiments are subjected to a battery of mechanical, electromagnetic and vibrational tests. This phase can take months or even years.



Development and qualification

Pre-op prep



Every possible anomaly—from a failure to start to signal loss—is anticipated and the related procedure set down in writing.

To be prepared for any eventuality when it's time to conduct the experiment in space, the control centre rehearses the sequence of operations and prepares the scientific follow-up.

It takes several years to devise the science and technology experiments that will fly on the ISS, and to develop and space-rate the required hardware for orbital flight. Behind each experiment lies the determination of researchers and

engineers to turn a research idea into an operational protocol robust enough for space. It's a painstaking process, but the mission's scientific success depends upon it. Once accomplished in orbit, experiments continue their lifecycle in ground

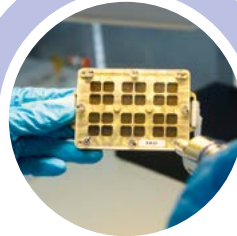
labs, as the data collected are analysed and extrapolated. The epsilon mission is carrying a suite of French experiments, including seven prepared and controlled by CADMOS.

Operating in orbit



Once aboard the ISS, each experiment is carried out by the astronaut under close supervision from CADMOS engineers on the ground. For the epsilon mission, several astronauts including Sophie Adenot have been working on EchoFinder, a device that combines augmented reality with AI to produce autonomous ultrasound scans.

It takes hours, days or even weeks for the data to be collected and shared with the scientific community. They are stored on hard drives, the largest of which are ferried back to Earth. For certain experiments like MatISS², hardware is sent back to Earth for analysis.



Extrapolating results

² Experiment to collect and analyse micro-organisms in the air aboard the ISS.

Earth attractions



Exhibition: Three centuries of French exploration

“Exploration: A State Affair?” was held at France’s national military museum in Paris from April to June of this year.

Covering 300 years of French exploration, from the ocean depths to major space missions, the exhibition showcased archives, scientific and technical artefacts, works of art and first-hand accounts to trace the history of France’s great sea voyages, scientific expeditions and surveys, driven by strategic, colonial or technological ambitions. Exhibits included a spacesuit and CNES mock-ups of the Perseverance rover and Yoda satellite.

Poetry in orbit with epsilon

Organized by CNES, publishers Milan and the Printemps des Poètes poetry festival, the *Astropoèmes* competition challenged pupils from 5 to 15 to write up to 20 verses on the theme of space and dreams. Four winners were selected from the 2,903 participants for originality, pertinence, style and spelling. And the top entry, chosen by judging panel president Sophie Adenot, was read out on the ISS!



CNES store: A backpack for school or space!

Any aspiring astronaut needs to be well-equipped! Made in CNES, this sturdy 100% organic cotton backpack will prove a loyal companion, whether your adventures are Earth or space-bound! Ethically handcrafted in India by an NGO committed to women’s empowerment, it’s as meaningful as it is practical.

Available on maboutique.cnes.fr – €59.90.



Astronauts for a day!

———— The 2026 edition of CNES's **Astronaut for a Day competition** (*Astronaute d'un jour*) gave 2,256 young teens the chance to go on a parabolic flight and experience microgravity for themselves. Candidates from several schools were grouped randomly and given a series of collaborative challenges. Acting as scientists or astronauts, they had to calculate the parameters of a space mission, set up scientific experiments on the ISS and handle an emergency landing. Their powers of judgment were also put to the test, to separate fact from fiction in a disturbing account involving UAPs, just like investigators at GEIPAN, the French UAP research and information group. This April, the 80 kids selected were joined by 20 young people with disabilities to compete in the astro-sports team final. And in June, the 30 overall winners got the incredible opportunity to experience weightlessness in the cabin of the Airbus Zero-G (see Space take, p.11).

Cap sur l'Espace at the Cité des Sciences



———— Some 20,000 visitors, young and old, made the most of the range of free space activities on offer at the weekend-long **Cap sur l'Espace** event at La Villette in Paris organized by CNES in partnership with ESA on the sidelines of the **International Space Summit**. The event gave families the chance to learn all about the space adventure, with mock-up displays, virtual-reality experiences, educational workshops and conferences. Our experts were on hand to answer questions and share their passion. Astronauts Thomas Pesquet and Arnaud Prost took the opportunity to launch a naming competition for their future space missions. The event was a huge success that will hopefully inspire new vocations.

An orbital journey into sound



———— The **OSCAR device** was developed to write music in harmony with space.

Attached to the ISS's external Bartolomeo platform since 2024, its compositions are a direct result of its environment, with temperature, light and vibration all influencing the pitch and rhythm of its notes. OSCAR returned to Earth in February

2026 with the equivalent of 303 hours of piano pieces composed in orbit. The brainchild of artist Stéphane Thidet and produced by the Observatoire de l'Espace, the cultural arm of CNES, this unique musical experiment will be released on Earth in 2027, as a sound installation.

The world human spaceflight club

Today, a wider circle of agencies has joined the elite club of nations with a stake in human spaceflight and space exploration, for many years the preserve of the world's two superpowers. We take a closer look at those with skin in this game, from legacy players to those with more recent ambitions.

PIONEERS: UNITED STATES, RUSSIA

In the 1960s, the Americans and Soviets sent the first humans into space and later built orbital stations that would mark the history of human spaceflight. Today, the two nations still share crews aboard the International Space Station (ISS), but they are taking different paths, the United States shooting for the Moon with Artemis, while Russia is turning to China and the International Lunar Research Station (ILRS) programme.

RISING POWERS: CHINA, INDIA

Having remained outside the ISS adventure, these two nations are now moving ahead on their own. China launched its first Tiangong space station in 2011 and today has a permanent crew of taikonauts in orbit. Its ambition is to set foot on the Moon in 2029, to mark the 80th anniversary of the People's Republic. India's human spaceflight programme is more recent, but it has big ambitions, seeking to land on the Moon by 2040. Both nations are betting on an independent capability as a symbol of their power.

ISS PARTNERS: EUROPE, JAPAN, CANADA

With the launch of the ISS in the late 1990s, the old rivalry between Washington and Moscow gave way to an international adventure pursued by a circle of partners. Europe, Japan and Canada would contribute modules, scientific experiments and a robotic arm. These space agencies' human spaceflight efforts are driven by cooperation: in other words, they don't have their own programme but rather are playing a pivotal role underpinned by world-class technological contributions.

NEWCOMERS: UNITED ARAB EMIRATES, SAUDI ARABIA

For these two nations, human spaceflight is more a strategic instrument than an industrial project. Sending astronauts into space projects an image of a modern country on the international stage, while getting their people interested in science and preparing for the post-oil era. Soft power and economic diversification are guiding space ambitions built on partnerships rather than independent capabilities.



